

## PATENT COOPERATION TREATY

**PCT**

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

REC'D 10 FEB 2006

WIPO

PCT

Applicant's or agent's file reference 30794108WO01		<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/US03/39211	International filing date (day/month/year) 09 December 2003 (09.12.2003)	Priority date (day/month/year)	
International Patent Classification (IPC) or national classification and IPC IPC(7): H01L 21/465, 29/06, 29/20, 33/00 and US Cl.: 257/98, 103; 438/43, 47			
Applicant FUJII ET AL.			
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of <u>3</u> sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of <u>5</u> sheets.</p> <p>3. This report contains indications relating to the following items:</p> <p>I <input checked="" type="checkbox"/> Basis of the report</p> <p>II <input type="checkbox"/> Priority</p> <p>III <input type="checkbox"/> Non-establishment of report with regard to novelty, inventive step and industrial applicability</p> <p>IV <input type="checkbox"/> Lack of unity of invention</p> <p>V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</p> <p>VI <input type="checkbox"/> Certain documents cited</p> <p>VII <input type="checkbox"/> Certain defects in the international application</p> <p>VIII <input type="checkbox"/> Certain observations on the international application</p>			
Date of submission of the demand 23 May 2005 (23.05.2005)		Date of completion of this report 01 December 2005 (01.12.2005)	
Name and mailing address of the IPEA/US Mail Stop PCT, Attn: IPEA/ US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201		Authorized officer Tom Thomas Telephone No. 571-272-1630	

Form PCT/IPEA/409 (cover sheet)(July 1998)

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/US03/39211

**I. Basis of the report**

## 1. With regard to the elements of the international application:\*

- ☐ the international application as originally filed.
- ☒ the description:  
pages 2-15 as originally filed  
pages NONE, filed with the demand  
pages 1, filed with the letter of 13 October 2005 (13.10.2005).
- ☒ the claims:  
pages NONE, as originally filed  
pages 16-18/1, as amended (together with any statement) under Article 19  
pages NONE, filed with the demand  
pages NONE, filed with the letter of \_\_\_\_\_.
- ☒ the drawings:  
pages 1-10, as originally filed  
pages NONE, filed with the demand  
pages NONE, filed with the letter of \_\_\_\_\_.
- ☐ the sequence listing part of the description:  
pages NONE, as originally filed  
pages NONE, filed with the demand  
pages NONE, filed with the letter of \_\_\_\_\_.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language \_\_\_\_\_ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in printed form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages NONE
- ☐ the claims, Nos. NONE
- ☐ the drawings, sheets/fig NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).\*\*

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.  
PCT/US03/39211

**V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

**1. STATEMENT**

Novelty (N)	Claims <u>1-26</u>	YES
	Claims <u>NONE</u>	NO
Inventive Step (IS)	Claims <u>1-26</u>	YES
	Claims <u>NONE</u>	NO
Industrial Applicability (IA)	Claims <u>1-26</u>	YES
	Claims <u>NONE</u>	NO

**2. CITATIONS AND EXPLANATIONS**

Claims 1-26 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest a III-nitride LED having the N-face surface roughened.

Claims 1-26 meet the criteria set out in PCT Article 33(4), and thus meet industrial applicability because the subject matter claimed can be made or used in industry.

----- NEW CITATIONS -----

# HIGHLY EFFICIENT (B,Al,Ga,In)N BASED LIGHT EMITTING DIODES VIA SURFACE ROUGHENING

## 1. Field of the Invention.

The invention is related to light emitting diodes, and more particularly, to highly efficient (B,Al,Ga,In)N based light emitting diodes via surface roughening.

## 5 2. Description of the Related Art.

(Note: This application references a number of different publications as indicated throughout the specification by one or more reference numbers. A list of these different publications ordered according to these reference numbers can be found below in the section entitled "References." Each of these publications is  
10 incorporated by reference herein.)

Gallium nitride (GaN) based wide band gap semiconductor light emitting diodes (LEDs) have been available for about 10 years. The progress of LED development has brought about great changes in LED technology, with the realization of full-color LED displays, LED traffic signals, white LEDs and so on

15 Recently, high-efficiency white LEDs have gained much interest as possible replacements for fluorescent lamps. Specifically, the efficiency of white LEDs (74 lm/W) [1] is approaching that of ordinary fluorescent lamps (75 lm/W). Nonetheless, more improvement in efficiency is desirable.

There are two principle approaches for improving LED efficiency. The first  
20 approach is increasing the internal quantum efficiency ( $\eta_i$ ), which is determined by crystal quality and epitaxial layer structure, while the second approach is increasing the light extraction efficiency ( $\eta_{\text{extraction}}$ ).

Increasing the internal quantum efficiency cannot readily be done. A typical  
25  $\eta_i$  value for blue LEDs is more than 70% [2] and an ultraviolet (UV) LED grown on a low-dislocation GaN substrate has recently exhibited an  $\eta_i$  of about 80% [3]. There is little room for improvement of these values.

## WHAT IS CLAIMED IS:

1. A (B,Al,Ga,In)N based light emitting diode (LED), wherein light is extracted through a nitrogen face (N-face) of the LED and a surface of the N-face is  
5 roughened.
2. The LED of claim 1, wherein the surface of the N-face is roughened into one or more cones.
- 10 3. The LED of claim 1, wherein the roughened surface reduces light reflections occurring repeatedly inside the LED, and thus extracts more light out of the LED.
4. The LED of claim 1, wherein the surface of the N-face is roughened by  
15 an anisotropic etching.
5. The LED of claim 4, wherein the anisotropic etching is a dry etching.
6. The LED of claim 4, wherein the anisotropic etching is a photo-  
20 enhanced chemical (PEC) etching.
7. The LED of claim 1, wherein the N-face is an n-type layer of the LED.
8. The LED of claim 1, wherein the N-face is prepared by a laser lift off  
25 (LLO) technique.
9. The LED of claim 1, wherein the LED is grown on a c-plane gallium nitride (GaN) wafer and a gallium face (Ga-face) is a p-type layer.

PCT/US03/39211 13102003

10. The LED of claim 1, wherein the LED is comprised of an n-type electrode, n-type layer, active region, p-type layer and p-type electrode.

11. The LED of claim 10, wherein the n-type layer, active region and p-type layer are each comprised of a (B, Al, Ga, In)N alloy.

12. The LED of claim 10, wherein the p-type electrode has a property of high reflection to decrease light absorption and to increase light reflection toward the surface of the n-type layer.

10

13. The LED of claim 10, wherein the LED includes a current-blocking layer aligned under the n-type electrode to keep the current from concentrating below the n-type electrode, so that absorption of light emission under the n-type electrode can be avoided and extraction efficiency can be increased.

15

14. The LED of claim 10, wherein the LED includes a current-confining frame made of an insulator to restrain leakage current through the sidewalls of the LED without significantly decreasing an emitting area.

15. The LED of claim 2, wherein the roughened surface is comprised of a plurality of hexagonal shaped cones that have an angle equal to or smaller than:

$$2 \sin^{-1}(n_{air} / n_s) \approx 47.2^\circ$$

for a gallium nitride (GaN) LED, where  $n_{air}$  is a refractive index of air and  $n_s$  is a refractive index of GaN.

PCT/US2013/032411 43402003

16. The LED of claim 2, wherein the roughened surface is comprised of a plurality of hexagonal shaped cones that have an angle equal to or smaller than:

$$2 \sin^{-1}(n_{enc} / n_s)$$

5

for epoxy, where  $n_{enc}$  is a refractive index of epoxy and  $n_s$  is a refractive index of the LED.

17. A method of creating a (B,Al,Ga,In)N based light emitting diode (LED), wherein light is extracted through a nitrogen face (N-face) of the LED, comprising:

roughening a surface of the N-face into one or more cones.

18. The method of claim 17, wherein the roughening step is performed using an anisotropic etching.

19. The method of claim 18, wherein the anisotropic etching is a dry etching.

20. The method of claim 18, wherein the anisotropic etching is a wet etching.

21. The method of claim 20, wherein the wet etching is a photo-enhanced chemical (PEC) etching.

22. A light emitting diode (LED) comprised of an n-type electrode, n-type layer, active region, p-type layer and p-type electrode, wherein a nitrogen face (N-face) surface of the n-type layer is roughened into one or more cones and light is extracted through the roughened N-face surface of the n-type layer.

23. The method of claim 22, wherein the N-face surface of the n-type layer is roughened using an anisotropic etching.

24. The method of claim 23, wherein the anisotropic etching is a dry etching.

5 25. The method of claim 23, wherein the anisotropic etching is a wet etching.

26. The method of claim 25, wherein the wet etching is a photo-enhanced chemical (PEC) etching.

10

18/1

19

AMENDED SHEET